RECOMMENDED STANDARDS FOR ALTERNATING CURRENT IN COAL MINES

By Bureau of Mines Health and Safety Staff

* * * * * * * * * * * information circular 7962

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Marling J. Ankeny, Director

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RECOMMENDED STANDARDS FOR ALTERNATING CURRENT IN COAL MINES[1]

by

Bureau of Mines Health and Safety Staff

Although alternating-current (a.-c.) power systems and equipment have been used in coal mining for many years, most mines in the United States are powered mainly by direct current (d.-c.). There are several logical reasons for this, but the use of d.-c. equipment is, in most instances, a direct outgrowth of the original practice of using such power for haulage systems.

For traction equipment such as the electric trolley locomotive the d.-c. motor has ideal operating characteristics, and thus it has been widely used for haulage locomotive service. The first efforts at electrification of coal mines started with the haulage system and from there branched out to include the many types of electrically powered mining machinery used in the industry today.

The continued extension of d.-c. systems in underground mines has introduced many problems concerned with fire and explosion hazards, as well as difficulties in transmission of power and in maintenance of equipment. For these reasons there has been a definite trend in recent years toward greater use of a.-c. power systems in the coal mining industry.

Many of the difficulties encountered in the use of d.-c. power systems undoubtedly have been created by the lack of guidance and technical experience available to the mine operator in the early days of mine electrification. Mistakes made in original planning and execution have been amplified by the growth of the systems. Now, as the pattern of electrification changes and the trend is toward greater utilization of a.-c. equipment in coal mining, there is a need for information concerning the best practices in the industry. It is the purpose of this circular to present such information, together with recommended standards for the installation of a.-c. power systems and equipment.

The mine operator who plans to operate a mine with alternating current, or any mine official responsible for the efficiency or safety of such an operation, should be familiar with the advantages of its use. He also should have some knowledge of the advantages and disadvantages of one system over another, both from the standpoint of safety and efficiency.

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[1] Work on manuscript conpleted October 1959.

Nearly all a.-c. power systems used in mining are of the three-phase types. Single-phase circuits may be derived from three-phase circuits for the operation of small motors either at phase-to-phase voltage or at the lower phase-to-neutral voltage, and such circuits are encountered frequently in coal mine service.

By comparison with d.-c. power systems there are certain advantages in safety to be obtained by the use of a.-c. systems. One inherent safety advantage is the greater ease with which circuit interruption can be accomplished under short-circuit conditions. This greatly lessens the possibility of fires resulting from faults in cables serving portable or mobile mining equipment. The greater facility with which alternating current can be transmitted and transformed to different voltages is also advantageous from a safety standpoint. Modern transformers are relatively trouble free and can be obtained either in ventilated dry type, sealed dry type, or liquid cooled with nonflammable liquids.

Electric shock hazards are reduced because the line to ground voltage on a.-c. systems can be held to a value only slightly greater than one-half the line voltage by the use of grounded neutrals. In addition, a.-c. squirrel cage motors are relatively spark free in normal operation, and maintenance costs are lower.

These and other advantages of a.-c. systems are discussed in this circular, and examples of such installations in practical coal mining service are included.

ACKNOWLEDGMENTS

The Bureau of Mines is indebted to the American Mining Congress, Underground Power Committee for its wholehearted cooperation, suggestions, and critical review of the Recommended Standards, and to O. J. Swanson and his subcommittee for its review and revision.

Credit is also extended to George Trevorrow, Safety Director, Bituminous Coal Operators Association; J. B. Benson, Directory of Safety, Southern Coal Producers Association; Harry Gandy, Jr., Director, Department of Safety, National Coal Association; and Charles Ferguson, Director, Safety Division, United Mine Workers of America, for their interest and helpful suggestions.

The Mining and Metals Industry Committee of the AIEE was also helpful in the preparation of the standards. R. R. Godard, District Electrical Engineer, United States Steel Corp. represented the committee and was responsible for numerous changes and improvements in the standards.

Several Bureau of Mines engineers reviewed the manuscript and suggested changes to conform as nearly as possible with best practice in various mining areas of the country.

The illustrations were obtained from mining and manufacturing companies or were prepared by engineers of the Bureau of Mines.

ALTERNATING-CURRENT SYSTEMS

Two general types of three-phase a.-c. power distribution systems are in use:

1. The ungrounded delta system, and

2. The wye-connected grounded neutral system.

Ungrounded Delta System

The ungrounded delta system as used in coal-mining practice usually originates in a bank of three single-phase transformers having their secondaries connected in the form of a delta, from which the system derived its name. The system is operated normally ungrounded and has some inherent advantages that have made it quite popular where continuity of operation is considered an important factor. On such a system one phase may be solidly grounded without affecting the operation of the system or equipment. With the ungrounded delta system, also, one transformer may be removed from a bank of three and operation continued as a normal three-phase system at about 56 percent of the original capacity of the bank. If a transformer becomes defective, this is a decided advantage. It is possible, also, to install a three-phase system of this kind using only two transformers and later, when the load increases, to add the third transformer with virtually no change in the system connections. Or, if three transformers have been installed in a delta bank and the load is reduced sufficiently, one transformer may be cut loose to be used elsewhere or to reduce the losses during periods of light load or no load.

The disadvantages of the ungrounded delta system are principally those relating to safety and are listed below:

1. The voltage from phase to ground or from equipment frames to ground may equal the phase-to-phase voltage of the system under fault conditions, thus increasing the shock hazards.

2. Increased voltage stresses are impressed on the insulation of motors and control equipment under fault conditions, increasing the possibility of further breakdown of the insulation.

3. It is difficult to provide effective ground-fault protection on such a system without adding special equipment.

4. Simultaneous ground faults may exist at remote points on the system without opening the protective devices, thus setting up ignition and fire hazards due to stray currents in the mine strata or other parallel current conducting paths.

Wye-Connected Grounded Neutral System

The modern trend in a.-c. practice is toward the use of the wye-connected system, with the neutral grounded and the grounding conductor carried along with the phase conductors. Such a system provides certain operating advantages, as well as better protective facilities for both the equipment and the operating personnel.

The wye-connected system in general use is preferred for distributing power in industry, principally because it is possible to provide better system protecting with the grounded neutral arrangement. There is, however, the important advantage of being able to distribute three-phase power at one voltage and single-phase power at another voltage over the same system. At the same time it is possible to maintain a reasonable degree of overall balance on the three-phase system.

From a safety standpoint, better protection can be obtained from lightning surges, because the system is solidly grounded and numerous paths to ground are provided through the equipment and earth connections to the neutral conductor. The grounded neutral system permits the ground-fault protective devices to function dependably. Furthermore, the phase-to-ground voltage is limited; and, unlike the ungrounded delta system this voltage can never equal the phase-to-phase voltage as long as the neutral is properly grounded.

RECOMMENDED SYSTEMS

Ungrounded delta-connected power systems are not recommended for distribution of a.-c. power underground. Where delta systems are used, however, acceptable protection can be provided by the use of interconnected, or "zigzag", grounding transformers to form a derived neutral for system grounding. Such grounding transformers make the delta system approximately equivalent to the grounded wye-connected system in safety and efficiency. The connections for a typical delta-connected system are shown in figure 1.

Wye-connected, grounded neutral systems are in general favor and are recommended here because of the inherent safety advantages they provide.

General practice in the industry is to install a resistor of suitable value in the neutral circuit to limit the current that can flow in the grounding circuit on phase-to-ground faults. This method has been used in conjunction with current transformers and relays or ground current trip coils to provide protection from electric shock and to remove power from the systems in the event of a ground-fault. Figure 2 shows the usual wiring arrangement for such a system.

In modern practice there is a definite trend toward the use of balanced flux or "doughnut" type transformers to provide current for the isolation of faulted circuits. The use of such transformers provides a reliable means for deenergizing a circuit. The effect of extraneous a.-c. or d.-c. ground currents are eliminated, thus minimizing false tripping, and isolation of individual circuits is more readily accomplished. A system of this kind is shown in figure 3.

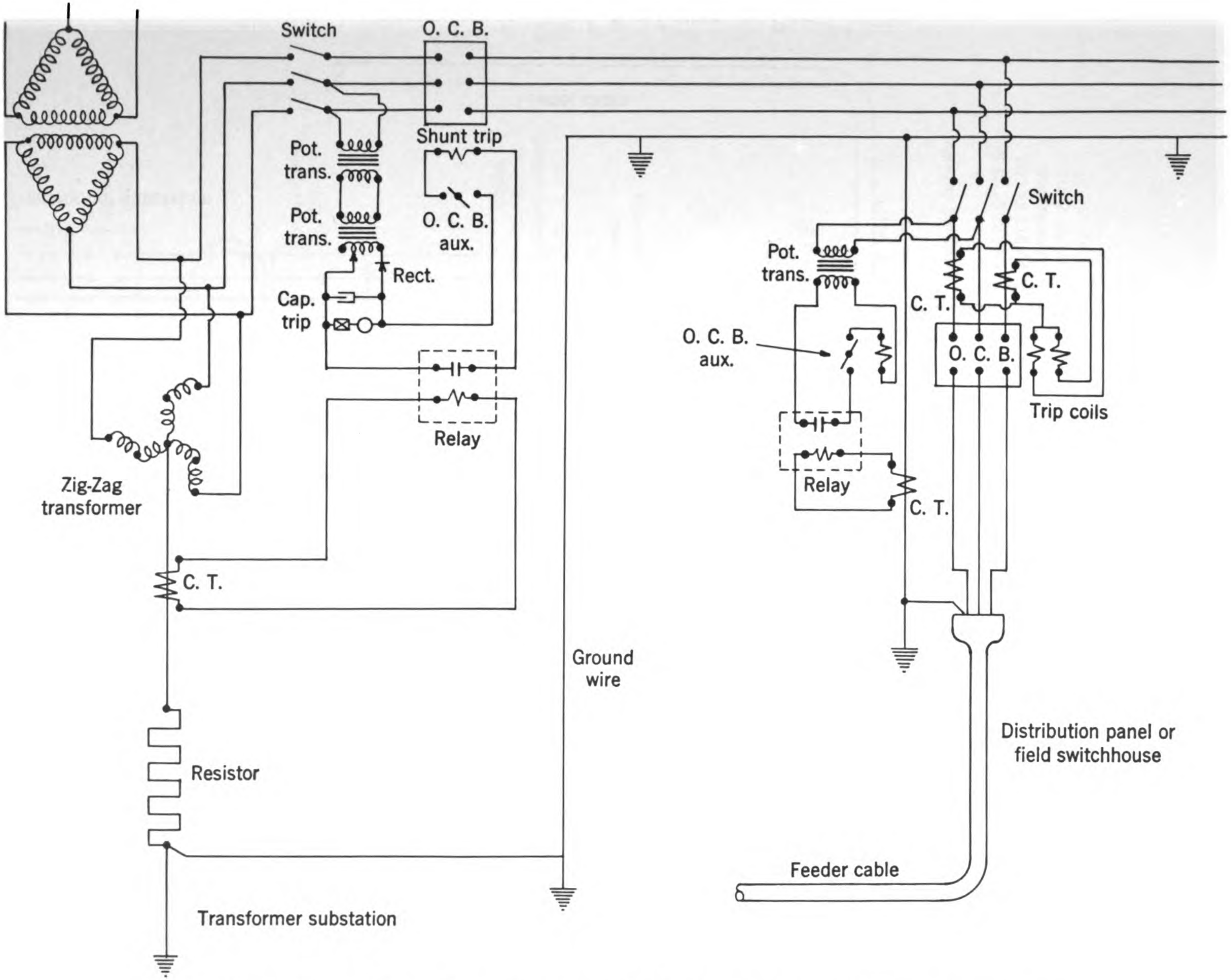

FIGURE 1. - Typical Delta-Connected Power System With Zig-Zag Grounding Transformer.

Original from THE OHIO STATE UNIVERSITY

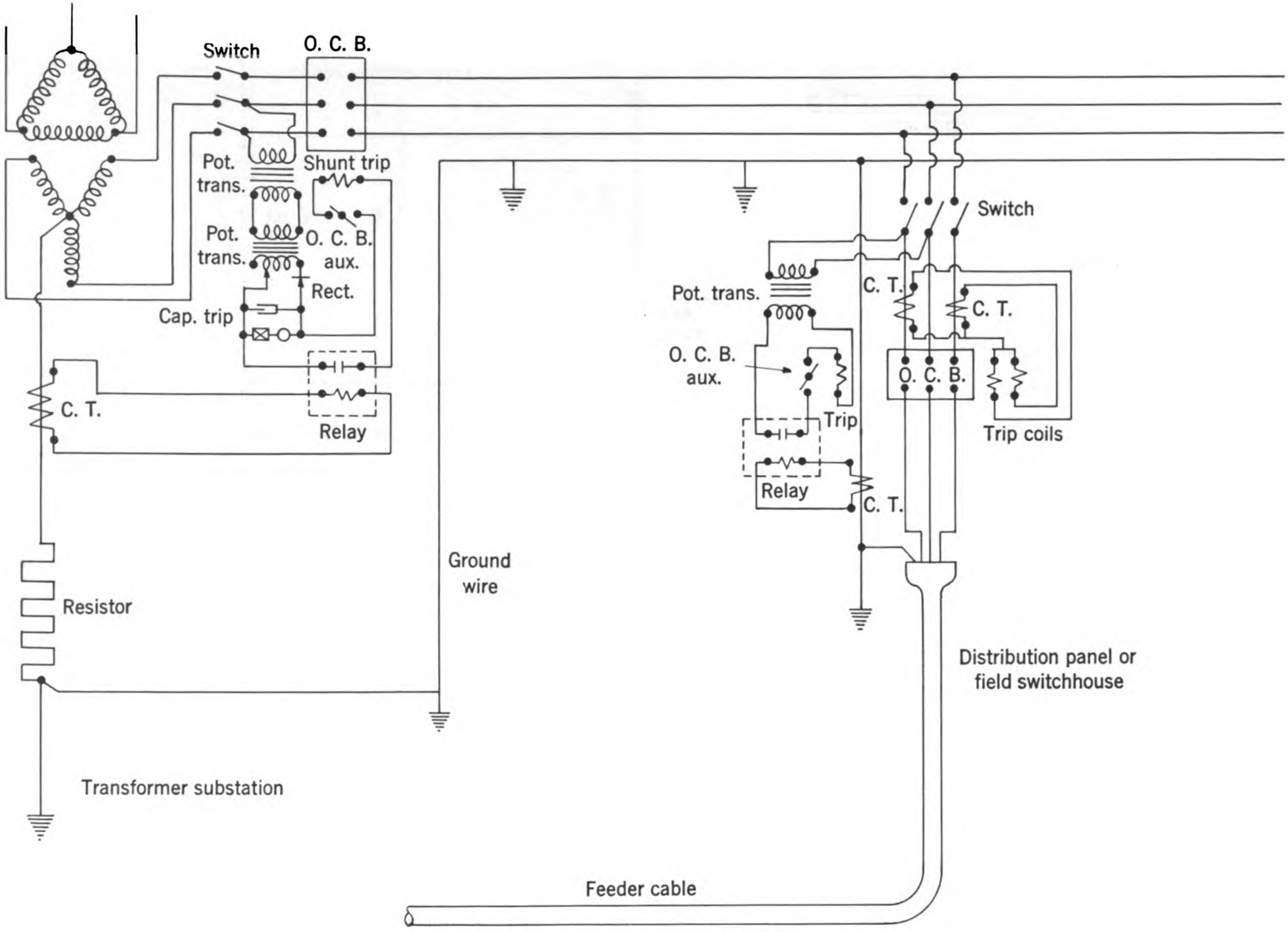

FIGURE 2. - Resistance Grounded, Wye-Connected Power System.

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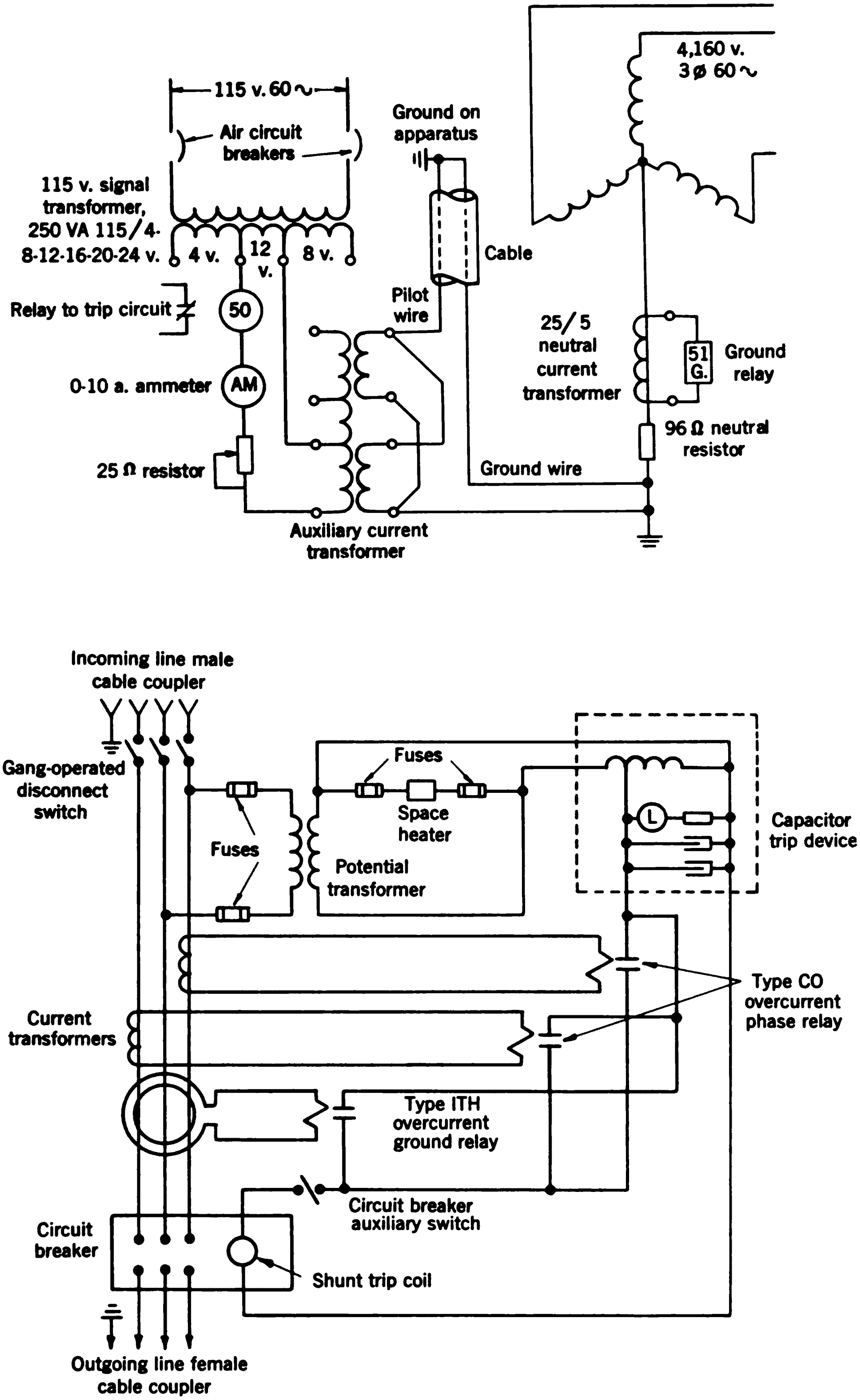
115 v. 60 ∿
Air circuit breakers
115 v. signal transformer, 250 VA 115/4-8-12-16-20-24 v.
4 v.
12 v.
8 v.
Relay to trip circuit
50
0-10 a. ammeter
AM
25 Ω resistor
Auxiliary current transformer
Ground on apparatus
Cable
Pilot wire
Ground wire
4,160 v. 3ø 60∿
25/5 neutral current transformer
51 G.
Ground relay
96 Ω neutral resistor
Incoming line male cable coupler
Gang-operated disconnect switch
Fuses
Potential transformer
Fuses
Space heater
L
Capacitor trip device
Type CO overcurrent phase relay
Current transformers
Type ITH overcurrent ground relay
Circuit breaker auxiliary switch
Circuit breaker
Shunt trip coil
Outgoing line female cable coupler

FIGURE 3. - Diagram Showing Use of Balanced Flux Transformers and Auxiliary Tripping Devices.

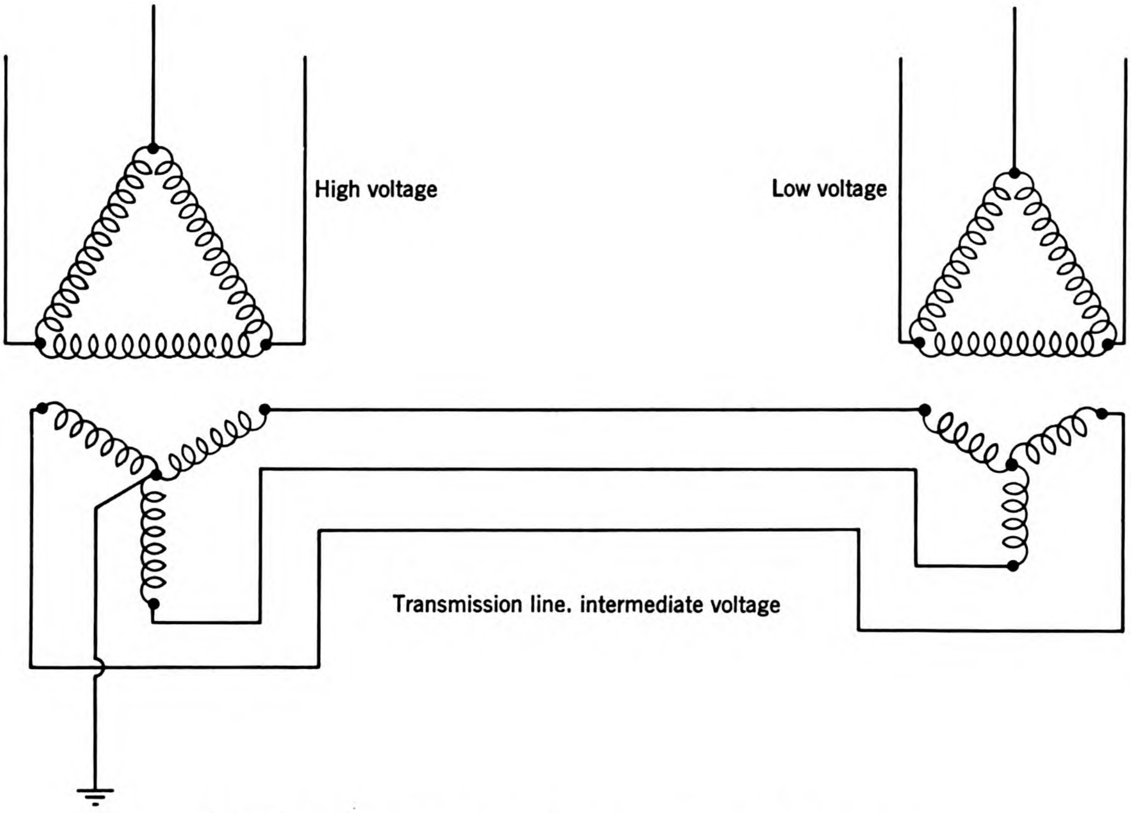

FIGURE 4. - Connection of Wye-Connected Transformer Secondaries to Wye-Connected Primaries.

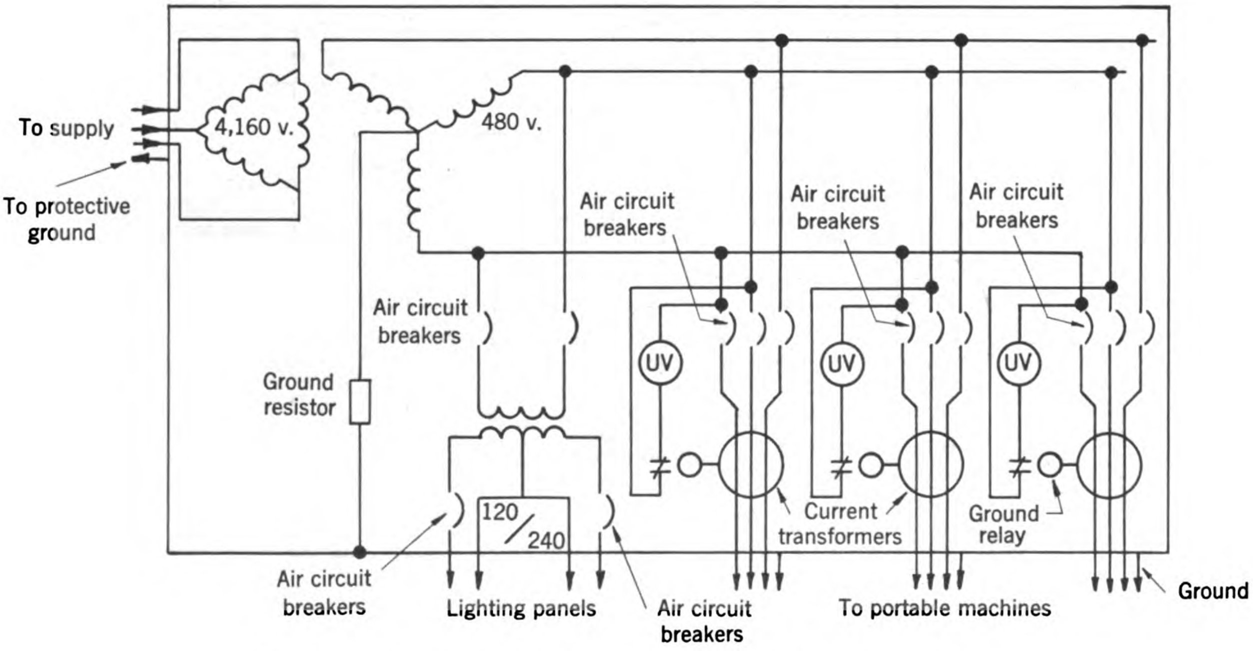

FIGURE 5. - Diagrams Showing Wiring of Typical Mine Power Center.

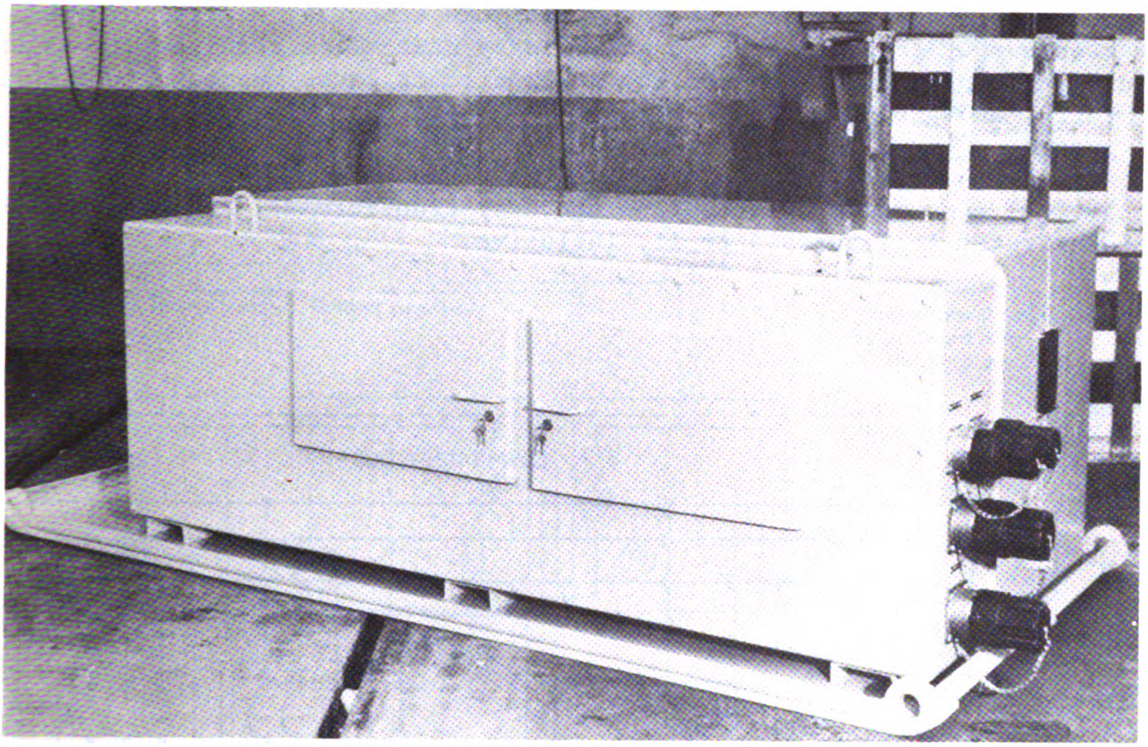

FIGURE 6. - Mine Power Center for A.-C. Distribution.

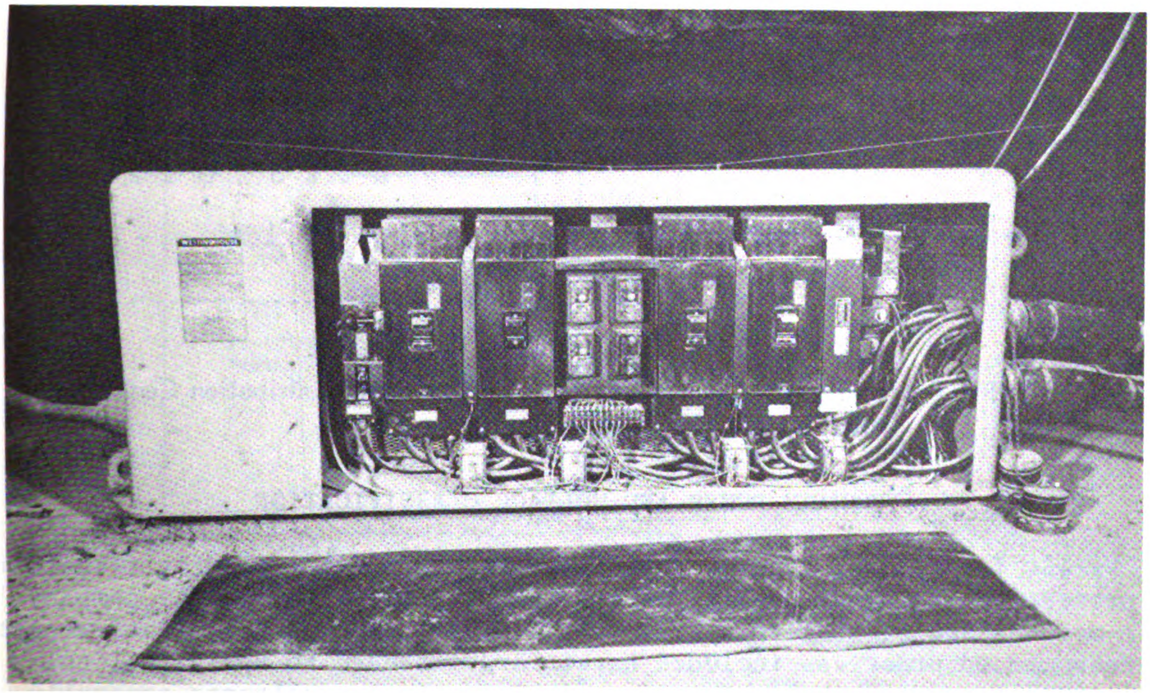

FIGURE 7. - Arrangement of Circuit Breakers and Auxiliary Equipment in Low-Voltage Distribution Center.

It is not good practice to ground both the secondary neutral of wye-connected supply transformers and the primary neutral of receiving transformers because unbalanced conditions on the power circuit cause currents to flow in the neutral and ground system. Figure 4 illustrates the proper connection for this system.

Typical mine power distribution centers, transformers, and connections are illustrated in figures 5 to 11, inclusive.

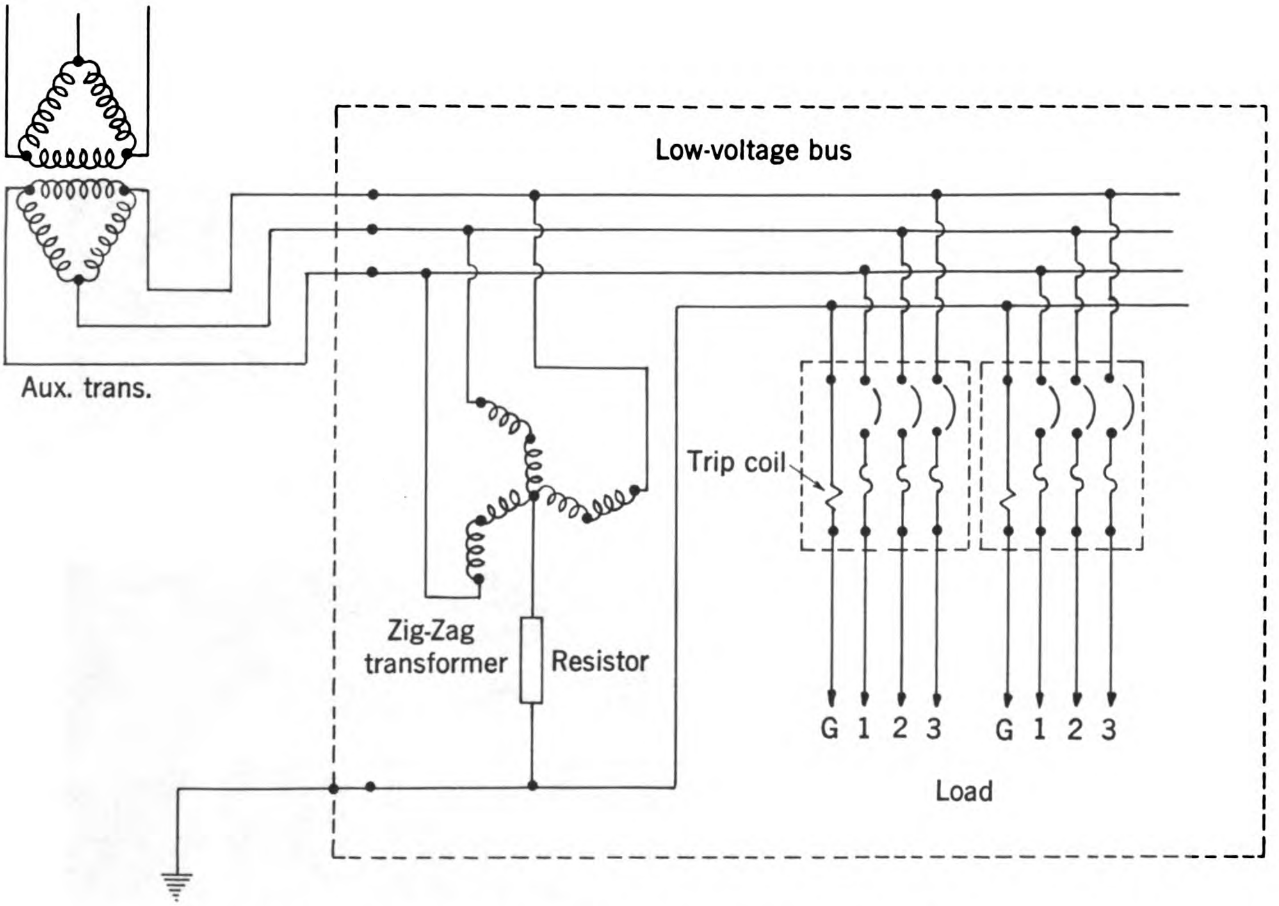

FIGURE 8. - Diagram Showing Circuits in Low-Voltage Distribution Center With Grounding Transformer.

PRIMARY POWER AND VOLTAGE CLASSIFICATION

Except for some of the larger mines, primary power including transformers and protective equipment usually is furnished by a public utility company whose methods and protective systems are well established. For this reason the recommended practices included herein are intended to apply to local transmission and distribution systems.[2] Transmission voltages generally will

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[2] American Standards Association, Preferred Voltage Ratings for A-C Systems and Equipment: C84.1 EEI-NEMA, 1954.

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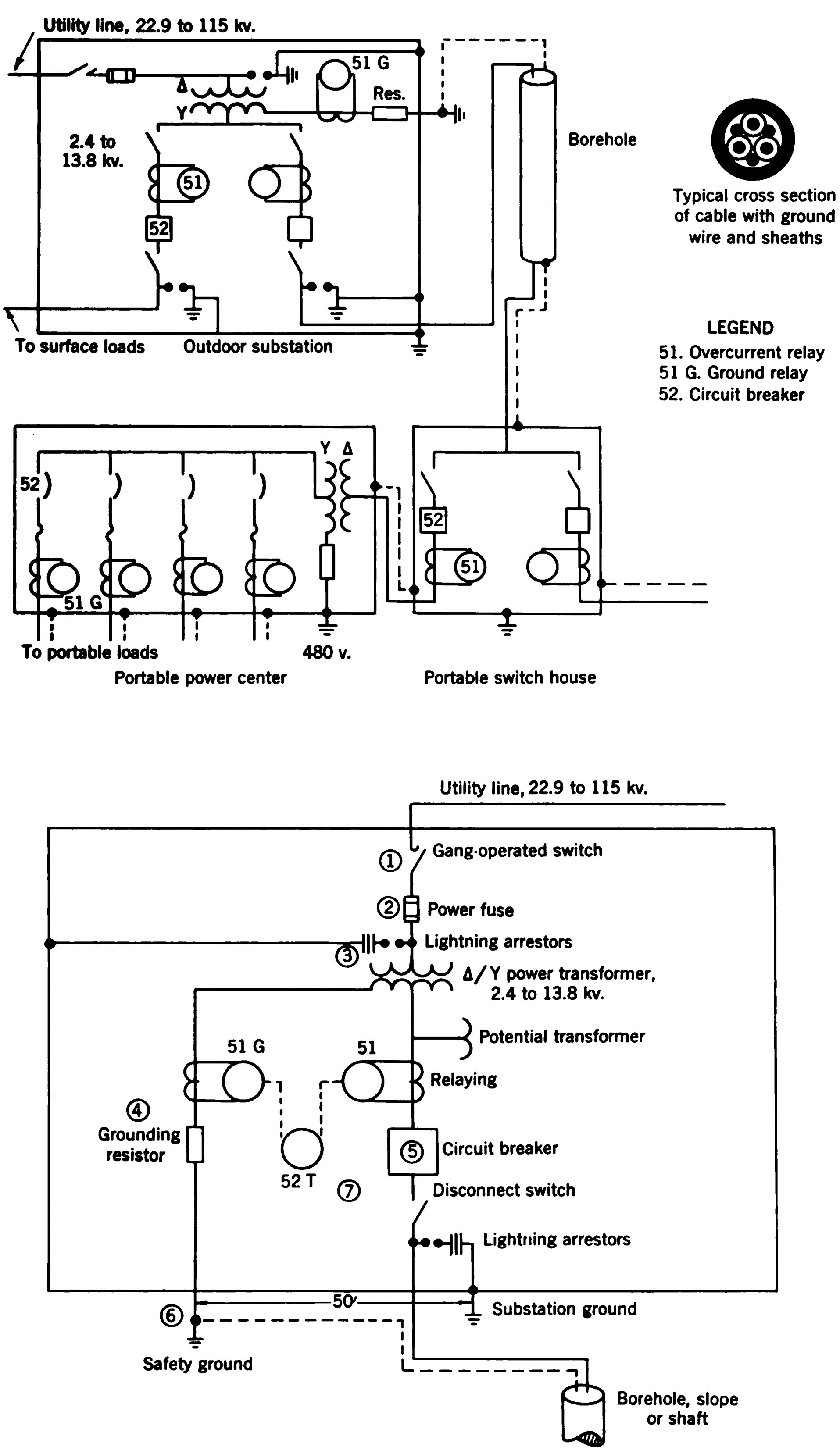

FIGURE 9. - Schematic Diagrams of Typical High-Voltage Circuit Arrangement.

Original from THE OHIO STATE UNIVERSITY

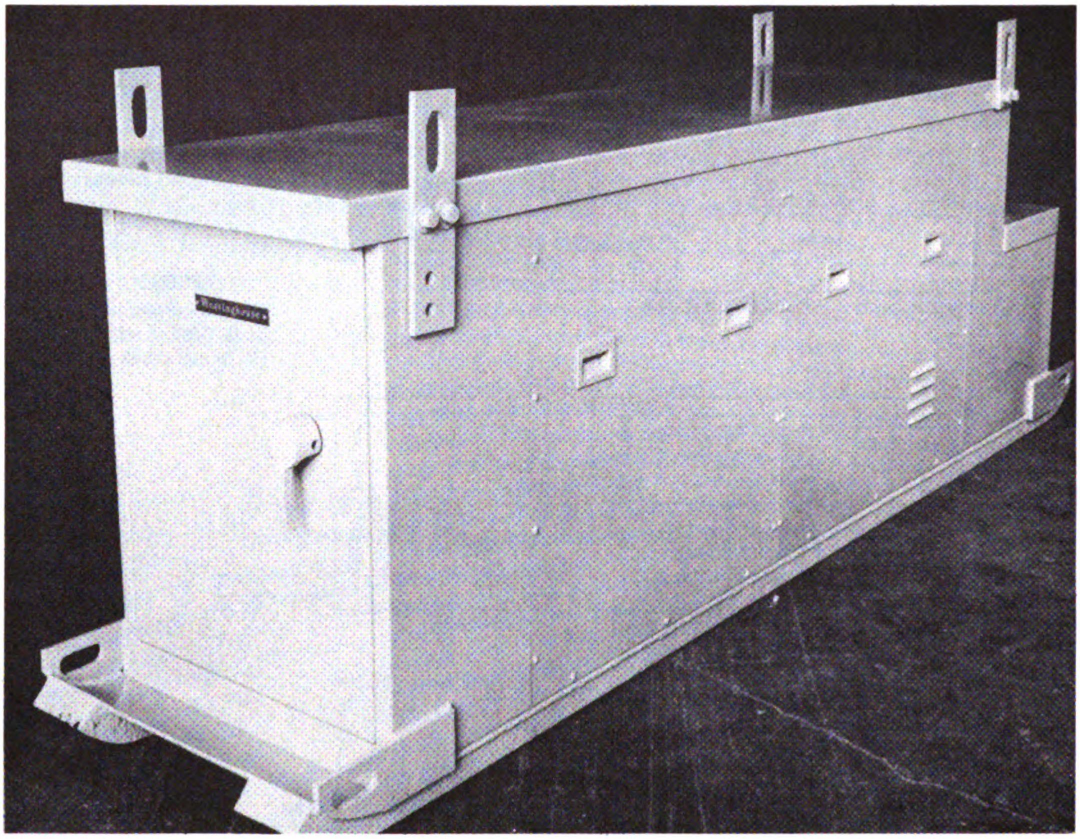

FIGURE 10. - Underground Portable Switchhouse With Single Triple Pole Oil Circuit Breaker.

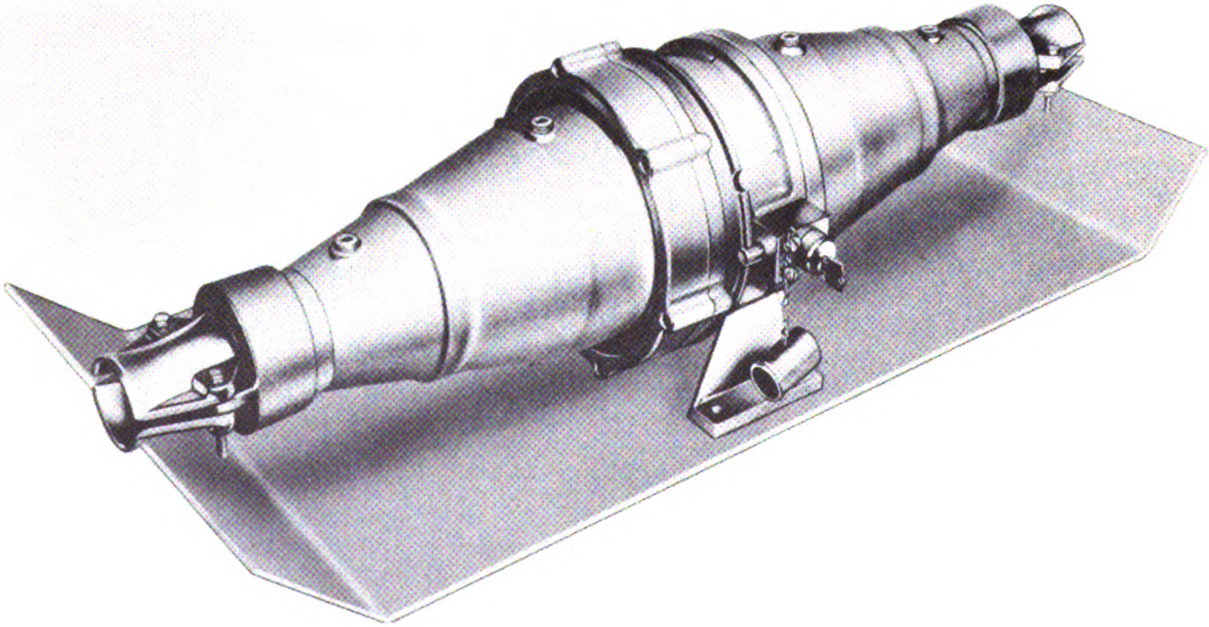

FIGURE 11. - Skid-Mounted High-Voltage Cable Coupler With Locking Arrangement.

be 2,400, 4,800, 7,200, or 12,000 for delta systems and 4,160, 8,320, or 12,470 for wye-connected systems, but may include such voltages as 7,620, 13,200, 14,400, and 23,000. Distribution voltages as considered here will generally be 120, 240, or 480 volts but may be higher. Generally, transmission voltages will be in the high-voltage class, and distribution voltages will be in the low-voltage class.

RECOMMENDED STANDARDS

Preface

The technical principles upon which these recommended standards are based are those generally accepted by the industry and proven safe in practice. They are not intended to limit or discourage development of other systems or devices for circuit protection and control. Such systems or devices should, however, provide, as a minimum, safety features comparable to those mentioned in this publication.

These standards should not be construed to supersede any State or Federal laws governing the use of electrical equipment in surface or underground mines.

Surface Installations

1.1 High-voltage distribution feeders for surface equipment should originate at the main transformer station or at suitable distribution centers. Protective equipment for such circuits should include an automatic circuit breaker of adequate rating provided with overcurrent protection and ground-fault protection where the system is grounded.

1.2 Frames, supporting structures, and enclosures of substation or switching station apparatus should be properly grounded.

1.3 Lightning arresters suitable for the voltage of the system should be installed on each ungrounded conductor on each exposed feeder circuit.

1.4 Buried cable for high-voltage distribution circuits for surface installations should be installed in accordance with accepted electrical practice for the type cable being used.

1.5 Terminations and splices of high-voltage cable should be made in accordance with manufacturer's recommendations.

1.6 The continuity of the cable shield or armor should be maintained through the splice, and the splice box, if used, should be grounded.

1.7 High-voltage cable installed in underground ducts or conduits, if provided with a metallic shield or shields over the individual insulated power conductors, should have the shield connected to the grounding system.

1.8 All metallic conduits and cable armor should be properly bonded to metallic switch boxes or enclosures which they enter, and conduit should be installed properly with locknuts and conduit end bushings to protect the wiring or cable from damage.

1.9 Indoor high-voltage oil circuit breakers, oil-filled starting compensators, and oil-filled load-break switches should be installed in fireproof buildings or in individual fireproof enclosures and remotely controlled. All housings enclosing oil switch gear should be ventilated effectively.

1.10 High-voltage switching equipment, except dead-front metal-clad gear, should be enclosed by a suitable fence, unless otherwise isolated from unauthorized personnel.

1.11 All high-voltage switchboards and switching equipment should be provided with a rubber mat or insulated platform of suitable voltage rating for the protection of operating personnel.

1.12 Surface buildings housing permanent or long-life major electrical equipment installations should be of fireproof construction or if not, fireproofing should be provided around open type switchboards and switching equipment.

1.13 High-voltage surface pole line circuits should be installed in accordance with local ordinance or applicable State and Federal regulations.

1.14 When used, ground or static wires for lightning protection should be mounted on poles above the uppermost power circuits, and circuits should be installed on the poles in descending order of voltage from the top down.

1.15 Poles, cross arms, insulators, and hardware should be of good grade, adequate for the service, and the conductors should be properly spaced and sagged.

1.16 Overhead ground wires should be brought down the poles at suitable intervals and grounded.

1.17 Where exposed overhead power lines enter surface buildings, lightning arresters should be installed at or near the entrance to the buildings.

1.18 Oil-filled transformers larger than 25 kv.-a. each in surface buildings should be installed in suitable vaults.

Underground High-Voltage Distribution

2.1 High-voltage circuits entering the mine should be protected by suitable circuit breakers of adequate interrupting capacity. Relaying circuits for this breaker should be in accordance with accepted electrical standards and should include protection against overcurrent and ground fault.

2.2 High-voltage circuits of the three-phase, delta connected type, should be provided with a derived neutral by the use of interconnected or zig-zag transformers, or other acceptable means. This neutral should be connected to ground through a suitable resistor at the source transformers, and a grounding conductor extended along with the phase conductors.

2.3 High-voltage circuits of the three-phase, wye-connected type should have the neutral point connected to ground through a suitable resistor at the source transformers, and a grounding conductor extended along with the phase conductors.

2.4 The grounding conductor should be connected to the equipment frames to prevent dangerous potential gradients on frames or ground under fault conditions.

2.5 High-voltage cables should be of the metallic armored type, or nonmetallic armored type having a flame resistant sheath or covering. A grounding conductor, or conductors, and one conductor insulated from the others should be provided and connected to deenergize the power circuit in case of an open grounding circuit. Cables should be shielded in accordance with I.P.C.E.A. Standard S-19-81. Metallic armor grounding conductors and metallic shielding should be connected to the grounding circuit to insure tripping of the circuit in case of insulation failure to ground on any phase conductor.

2.6 High-voltage cables in shafts or boreholes should be installed in the following manner:

Steel wire armored cables may be suspended by their armor from a suitable suspension unit.

Nonmetallic armored cables may be installed in shafts or boreholes by supporting at appropriate intervals by means of cable grips, ground wire, or by the conductors in accordance with manufacturers' recommendations. Where the cable may be exposed to falling material as in hoisting shafts suitable mechanical protection should be provided.

2.7 If lead sheathed cables are used, they should be provided with metallic armor or installed in conduit. Such cables should be terminated in sealed potheads or cable terminators.

2.8 Single-phase loads, such as transformer primaries, should be connected phase-to-phase.

2.9 Three-phase, wye-connected loads connected to high voltage circuits having grounded neutrals should not have their neutrals connected to ground.

2.10 The maximum voltage transmitted underground should not exceed that for which adequate circuit protection can be provided.

2.11 Conductor-shielding and grounding conductors should be connected to the supply transformer neutral or the established system neutral through a current limiting resistor. The ohmic value of the grounding resistor should be such as to limit the voltage drop in the grounding circuit external to the resistor to not more than 100 volts. The resistor should be rated for maximum ground fault current continuously and insulated from ground for a voltage equal to the phase-to-phase voltage of the system.

2.12 Lightning arresters having a voltage rating suitable for the voltage of the circuit should be installed on high-voltage circuits at or near the entrance to a mine where the incoming circuits feeding the mine are exposed to lightning.

2.13 Lightning arresters should be connected to a low resistance grounding medium on the surface which is separated from system and equipment grounds by a distance of not less than 10 feet.

2.14 High-voltage cables should be installed only in well maintained and accessible passageways of the mine.

2.15 High-voltage cables should be sectionalized at convenient intervals. Where the sectionalizing devices are not designed to open the circuit under load, a means of first tripping the outby circuit breaker should be provided.

2.16 High-voltage main feeder cables should extend to high-voltage distribution centers with breakers or disconnect switches supplying the branch circuits. Disconnecting devices should be incorporated to provide visual evidence that the circuit is deenergized when the switches are opened.

2.17 High-voltage cables subject to flexing should be similar to Type SH-D in accordance with I.P.C.E.A. Standard S-19-81.

2.18 High-voltage cables may be laid on the mine floor when protected from mechanical damage, supported on hangers, or, if attached to a messenger, may be supported from the roof. Extra lengths may be stored in a large figure 8 pattern, vertically on suitable supports, or horizontally in a protected location.

2.19 At locations where cables cross regular haulageways or travelways or where equipment must pass the cable, unless protected by sufficient height, should be installed in a trench in the roof, protected by some mechanical means, or buried at least 12 inches below combustible material and adequately protected from crushing by the weight of equipment passing over it.

2.20 Frames and enclosures of high-voltage switch units, transformers, metallic cable couplers, and splice boxes should be grounded to the common ground for the high-voltage system.

2.21 Circuit breakers and disconnecting switches underground should be adequately marked for identification and location. Where work is to be done on circuits or equipment, the devices used to remove power should be provided with means for locking them out to prevent accidental reclosing while men are working, and provision should be made for short-circuiting and grounding the deenergized circuit.

Transformers

3.1 Power transformers should not have their primary and secondary windings wye connected because of possible unstable operation.

3.2 High-voltage transformers installed underground should be of a dry type, installed in either a ventilated, nonventilated, or sealed enclosure and constructed with insulation having a minimum of organic materials, except that nonflammable liquid-filled transformers may be installed underground when ventilated by a separate split of air or where pressure diaphragms ducted to the air return are used.

3.3 Power transformers installed underground should be provided with adequate overcurrent protection and a suitable means of disconnecting the primary of the transformers to provide visual evidence that the circuit has been deenergized. Secondary circuits should be safety-neutral resistance-grounded and be provided with circuit breakers for outgoing feeders. Each secondary feeder circuit breaker should provide overcurrent and short circuit protection and ground-fault tripping. Suitable cable couplers or suitable cable terminators of the proper rating should be used.

Low Voltage Circuits

4.1 Low-voltage trailing cables should be of the flame resistant type, listed as having passed the cable damage resistance test Sec. 18.29, and the flame resistance test Sec. 18.30, Part 18, of Subchapter D (Bureau of Mines Schedule 2, revised, the latest revision of which is Schedule 2F), or subsequent revisions thereof.

4.2 Power circuits serving a.-c. face equipment should include a neutral grounding circuit, either direct or derived, the inby end of which should be connected only to the equipment machine frame.

4.3 Ground-fault protection on feeder circuits should be accomplished by means of a balanced-flux transformer and the neutral grounding circuit should be installed outside the transformer aperture and connected to the grounded side of the grounding resistor. The main bus breaker (if used) can be relayed through the neutral circuit.

4.4 If ground-fault protection is accomplished by means of a ground-trip coil, the outby end of the neutral grounding circuit should be connected to the system neutral on the grounded side of the grounding resistor.

4.5 Each individual power circuit (trailing cable) furnishing power to mining equipment should be protected from short circuit by means of an automatic circuit breaker that will open all three phases of the circuit simultaneously.

4.6 The maximum length of trailing cables should be 500 feet, except as permitted by applicable Bureau of Mines testing schedules.

4.7 Splices in trailing cables should be made in a workmanlike manner and well insulated. Not more than five temporary splices should be permitted in any trailing cable.

4.8 Cables in secondary circuits should be sectionalized to avoid excessive storage of energized cable.

4.9 Cable connectors employed for sectionalizing should be adequate for the service and should not present hazards when sections are attached or detached.

4.10 Cable and cable connectors should be adequately protected against damage while being transported or stored.

4.11 Cables in secondary circuits should be installed and protected so as to prevent mechanical damage.

4.12 Suitable cable fault finding equipment should be provided to facilitate cable repairs and minimize delays from faulted cables.

4.13 Where ground fault currents are limited by resistors, the grounding conductor in cables serving mobile equipment need not have a cross-sectional area equal to one-half of the area of the power conductor, except that in no case should it be less than No. 10 A.W.G., where the power conductors are No. 10 A.W.G. or larger. Where the power conductors are smaller than No. 10 A.W.G. the grounding conductor should be the same size as the power conductor.

Low Voltage (Under 650 Volts) Circuit Protection Other Than for Face Equipment

Reference: National Electric Code

5.1 Single-phase, 2-wire circuits, connected to single-phase ungrounded systems should be protected by a fuse in each conductor or by one double pole circuit-breaker with two overcurrent coils.

5.2 Single-phase, 2-wire circuits, connected to single-phase, 2-wire systems having the midpoint of the transformer grounded should be protected by a fuse in each conductor or by a double-pole circuit-breaker with two overcurrent coils.

5.3 Single-phase, 2-wire circuits, derived from three-phase, ungrounded neutral systems, should be protected by a fuse in each conductor or by a double-pole circuit-breaker with two overcurrent coils.

5.4 Single-phase, 2-wire circuits, derived from three-phase, grounded neutral systems, should be protected by a fuse in each conductor or by a double-pole circuit-breaker with two overcurrent coils.

5.5 Single-phase, 2-wire circuits, connected to single-phase systems with neutral ungrounded, should be protected by a fuse in each conductor or by a triple-pole circuit-breaker having three overcurrent coils (one in each ungrounded conductor).

5.6 Single-phase, 3-wire circuits, connected to single-phase 3-wire systems with grounded neutral should be protected by a fuse in each ungrounded conductor, or by a double-pole circuit breaker having two overcurrent coils (one in each ungrounded conductor).

5.7 Three-phase, 3-wire circuits, connected to three-phase 3-wire ungrounded systems should be protected by a triple-pole circuit-breaker with three overcurrent coils (one in each conductor).

5.8 Three-phase, 3-wire circuits, connected to three-phase grounded neutral systems should be protected by a triple-pole circuit breaker with three overcurrent coils (one in each conductor).

5.9 Three-phase, 4-wire circuits, connected to three-phase 4-wire, grounded neutral systems should be protected by a triple-pole circuit-breaker with three overcurrent coils (one in each ungrounded conductor).

5.10 If current transformers are used in lieu of series overcurrent trip coils, the number of current transformers should be the same for each installation as the number of overcurrent coils required in items 5.1 to 5.9 inclusive.

Illumination and Miscellaneous Power Tools

6.1 Face area lighting should utilize approved lighting systems installed in an approved manner as specified in Bureau of Mines Schedule 29 "Mine Lighting Equipment for Illuminating Underground Workings."

6.2 Transformers used to supply single-phase power for underground lighting or portable electrical equipment should have primary windings suitable for connection to the phase-to-phase voltage of the system on which they are used. Transformers should not be connected phase-to-neutral in any installation.

6.3 Handheld power tools operating at voltages in excess of 240 should not be used. All power tools should have their frames solidly grounded through a well maintained grounding conductor in their cables, the grounding conductor to be separate from power carrying conductors and the inby end connected only to the equipment frame or enclosure.

6.4 Stepdown or isolating transformers should have their frames grounded to the underground power system protective grounding conductor.

6.5 If a three-phase transformer is used to supply power to a handheld drill or portable tool, its secondary windings should be wye connected and the neutral connection brought out and grounded. The frames of equipment taking power from these transformers should be connected to this grounded neutral through a grounding conductor in the trailing cable.

General Provisions

7.1 Capacitors used for power-factor correction should be nonflammable liquid-filled. Suitable drain-off resistors or other means to protect workmen against electric shock following removal of power should be provided. Capacitors should be equipped with individual overcurrent fuses for short-circuit protection or with a suitable circuit breaker.

7.2 Where a.-c. to d.-c. conversion equipment is used to supply direct current for shuttle cars or other equipment, adequate electrical protection should be provided on both the a.-c. side and the d.-c. side of the conversion equipment.

7.3 Permanently installed conversion equipment underground, such as converters, motor generators, and transformers (mine power centers and rectifiers excepted), for supplying power to mining equipment and haulage systems should be installed in fireproof enclosures and ventilated by separate splits of air or provided with pressure diaphragms ducted to the return air course.

7.4 Where both a.-c. and d.-c. equipment is operating in the same mine, the grounding systems should not be interconnected.

7.5 A.-c. power systems should be engineered and maintained to provide not less than 90 percent of the normal voltage rating of the equipment at motor terminals at rated load.

DEFINITION OF TERMS

Some of the terms used in the foregoing text are well known electrical terms, while others have special meaning as applied to mining. Standard AIEE definitions have been used where they were applicable. However, where AIEE definitions were not suited to the text or where definitions had not been established, other sources were utilized. In each instance an attempt has been made to convey the particular meaning of the terms applying to this publication.

Approved.--Approved means in strict compliance with mining law or, in the absence of law, accepted by a recognized standardizing body or organization whose approval is generally recognized as authoritative on the subject.

Armored Cable.--An armored cable is a cable provided with a wrapping of metal, usually steel wires or tapes, primarily for the purpose of mechanical protection.

Authorized Person.--An authorized person is a person appointed by the official designated by the State mining laws as the one in charge of the operation of the mine to perform certain duties incident to the generation, transformation, and distribution or use of electricity in the mine. This person should be familiar with the construction and operation of the apparatus and with the hazards involved.

Borehole Cable.--A borehole cable is a cable designed for vertical suspension in a borehole or shaft and is used for power circuits in the mines.

Cable Shield.--A cable shield is a metallic shield consisting of nonmagnetic material applied over the insulation of the individual conductors or conductor assembly.

Cable Sheath (Non-metallic).--A cable sheath is a covering consisting of composition tapes, compound jackets of natural or synthetic rubber, thermoplastic, or fiber braids applied over the conductor assembly and insulation of multiple conductor cables.

Circuit Breaker.--A circuit breaker is a device for interrupting a circuit between separable contacts under normal or abnormal conditions.

Delta Connected.--A delta-connected power system is one in which the windings of transformers or a.-c. generators are connected to form a triangular phase relationship, and with the phase conductors connected to each point of the triangle.

Effectively Grounded.--Effectively grounded is an expression which means grounded through a grounding connection of sufficiently low impedance (inherent or intentionally added or both) so that fault grounds which may occur cannot build up voltages in excess of limits established for apparatus, circuits, or systems so grounded.

Electric System.--Electric system means all electric equipment and circuits that pertain to the operation of the mine and are under the control of the mine officials.

Face Equipment.--Face equipment is mobile or portable mining machinery having electric motors or accessory equipment normally installed or operated inby the last open crosscut in an entry or room.

Flame-Resistant Cable, Portable.--A flame-resistant cable is a portable cable that has passed the flame tests of the Federal Bureau of Mines.

Ground (Earth).--A ground is a conducting connection, whether intentional or accidental, between an electric circuit or equipment and earth or to some conducting body which serves in place of the earth.

Grounded (Earthed).--Grounded means that the system, circuit, or apparatus referred to is provided with a ground.

Ground or Grounding Conductor (Mining).--A grounding conductor (also referred to as a safety ground conductor, safety ground, and frame ground) is a metallic conductor used to connect the metal frame or enclosure of an equipment, device, or wiring system, with a mine track or other effective grounding medium.

High Voltage (High Potential).--High voltage is voltage having a nominal value greater than 650 volts between any two ungrounded conductors of the power system.

I.P.C.E.A.--I.P.C.E.A. is an abbreviation for Insulated Power Cable Engineers Association.

Lightning Arrester.--A lightning arrester is a protective device for limiting surge voltages on equipment by discharging or bypassing surge current; it prevents continued flow of follow current to ground and is capable of repeating these functions as specified.

Mine Power Center.--A mine power center is a combined transformer and distribution unit complete within a metal enclosure, usually of explosion-proof design, from which one or more low-voltage power circuits are taken.

Neutral Point.--A neutral point in a wye-connected a.-c. power system means the connection point of transformer or generator windings from which the voltage to ground is nominally zero, and is the point generally used for system grounding.

Neutral (Derived).--A derived neutral is a neutral point or connection established by the addition of a "zig-zag" or grounding transformer to a normally ungrounded delta power system.

Nonmetallic Armor.--Nonmetallic armor means a tough outer covering or cable sheath of rubber, rubber compound, or thermoplastic, designed to protect the cable conductors and insulation from abrasion or other damage from external sources.

Portable (Trailing) Cable.--A portable cable is a flexible cable or cord used for connecting mobile, portable, or stationary equipment in mines to a trolley system or other external source of electric energy where permanent mine wiring is prohibited or is impracticable.

Protection (Electrical).--Protection is provided by uses or other suitable automatic circuit-interrupting devices for preventing damage to circuits, equipment, and personnel by abnormal conditions, such as overcurrent, high or low voltage, and single-phasing.

Potential Gradient.--Potential gradient means an ascending or descending value of voltage related to a linear measurement, as a distance along the earth surface or ground.

Rectifiers.--Rectifiers as referred to in this publication mean mobile or portable rectifier units of the mercury-arc or semiconductor type that are normally mounted on trucks and/or enclosed in metal housings.

Wye-Connected (Y-Connected).--A wye-connected power system is a system in which one end of each phase winding of transformers or a.-c. generators are connected together to form a neutral point, and the other ends of the windings are connected to the phase conductors. A neutral conductor may or may not be connected to the neutral point, and the neutral may or may not be grounded.

Zig-Zag Transformer (Grounding Transformer).--A zig-zag transformer is a transformer intended primarily to provide a neutral point for grounding purposes.

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